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Copepods from ground waters of Western Australia, IV. Cyclopids from basin and craton aquifers (Crustacea: Copepoda: Cyclopidae)

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Abstract – *Halicyclops rochai* sp. nov. is described from a near-coastal aquifer in the Robe River basin. *Diacyclops reidae* sp. nov. and *Diacyclops einslei* sp. nov. are described from the Millstream aquifer in the western Fortescue Valley on the Pilbara craton. Records with large range extensions are given for *Paracyclops fimbriatus* (Fischer, 1853), *Diacyclops humphreysi* Pesce and De Laurentiis, 1996, *Microcyclops varicans* (G.O. Sars, 1863), *Metacyclops mortoni* Pesce, De Laurentiis and Humphreys, 1996 and *Mesocyclops brooksi* Pesce, De Laurentiis and Humphreys, 1996. The description of *D. humphreysi* is amplified. *Halicyclops rochai* sp. nov. belongs to a Tethyan group of species and is similar to *Halicyclops* sp. nov. Rocha *et al.* from the Yucatan Peninsula, Mexico. As such, it accords with the biogeographic affinities of non-copepod elements of the fauna.

INTRODUCTION

Arid northwestern Australia is proving to contain a diverse subterranean fauna in both terrestrial (Humphreys 1993c) and aquatic systems (Humphreys 1993a; papers in Humphreys 1993b). The stygofauna in particular contains many remarkable disjunct lineages in both anchialine (e.g. Yager and Humphreys 1996) and freshwater aquifers (Poore and Humphreys 1998), the existence, extent and affinities of which are only just being explored (Humphreys, in press a, in press b).

Cyclopoid copepods recently collected from the near-coastal areas of northwestern Australia have included the genera *Metacyclops* Kiefer, 1927 sensu Lindberg, 1961, *Mesocyclops* G.O. Sars, 1914, *Microcyclops* Claus, 1893, *Apocyclops* Lindberg, 1942, *Halicyclops* Norman, 1903 and *Diacyclops* Kiefer, 1927 (Pesce, De Laurentiis and Humphreys 1996a, 1996b; Pesce and De Laurentiis 1996). These studies greatly extended the range of some species and revealed a number of new species, some of which are restricted to groundwaters in this arid region.

The present paper examines material from the Pilbara craton (Millstream), a region of prolonged stability and not inundated by the sea since the Proterozoic (Hocking *et al.* 1987), as well as collections made on the coastal plains of Mesozoic age or younger (Yarraloola and Mardie Stations) that fringe the craton. Some collections from groundwaters in the Perth Basin are included.

HABITAT AND ASSOCIATED FAUNA

The area is arid with the annual evaporation exceeding the low annual rainfall (c. 350 mm) by about an order of magnitude, and is characterised by very high summer temperatures. The detailed environment is unknown, but water chemistry data are available for a number of sites.

Millstream – The Millstream aquifer, in Tertiary valley fills of palaeodrainage channels on the Pilbara craton, is in a karstic groundwater calcrete and freshwater (TDS 864 mg L^{-1} [s.e. 128.8, n=6]—raw data from pump tests in Barnett and Commander 1985) with a pH of 7.4±0.09. The characteristics of the Millstream aquifer and its geological context have been discussed at length by Poore and Humphreys (1998), together with the potential great age of the associated fauna (see also Humphreys 1993a, in press b). Forty-six locations were sampled in the Millstream aquifer, of which 20 yielded fauna of some type (16 piezometers, three wells, one water bore).

The associated fauna in the aquifer includes a new genus of Spelaeogriphacea, the first record of the order in Australasia (Poore and Humphreys 1998), as well as other elements of a clearly Gondwanan fauna, *inter alia* a genus of water mites previously known only from India (Harvey 1998), syncarids (Bathynellacea), phreatoicid isopods, phreodrilid oligochaetes, and also hydrobioid gastropods, ostracods and crangonyctoid amphipods.

Mardie and Yarraloola Stations, Carnarvon Basin – The aquifers are in gravel fans resulting from the discharges through water gaps respectively of the Fortescue and Robe Rivers from the Pilbara craton onto the coastal plain of the Carnarvon Basin (Commander 1994a, 1994b). They lie unconformably on Precambrian banded iron

Map 1 Sampling locations mentioned in the text. 1, Millstream; 2, Mardie Station; 3, Yarraloola Station; 4, Cossack; 5, Port Hedland; 6, Perth Basin. Millstream is on the Pilbara craton while Mardie and Yarraloola Stations lie to its west, in the Carnarvon Basin.

formation (Proterozoic schist in the case of the Robe Valley) and basalt, Cretaceous conglomerate and siltstone, and on Tertiary pisolite and limestone (ibid.). Groundwater salinity ranges from 345 mg L^{-1} (TDS) close to the river to 1200 mg L^{-1} near the tidal flats where there is a saltwater interface (ibid.). Samples were taken from 35 bores and pastoral wells in two groundwater assessment borefields. The fauna of these aquifers includes elements of the Tethyan fauna found on the Cape Range peninsula and Barrow Island (Humphreys 1993a, in press a) including atyid shrimp, cirolanid isopods and thermosbaenaceans, as well as diverse amphipods (Paramelitidae, Bogidiellidae: J. Bradbury, pers. comm. 1997; Bradbury and Williams 1997), ostracods, bathynellid syncarids, halacarid mites, hydrobioid gastropods and microturbellarians.

Perth Basin – Samples were taken from a number of groundwater monitoring bores in unconfined aquifers in Quaternary-Late Tertiary deposits of the Perth Basin (Davidson 1995), north of the Swan River and bordering the Yilgarn craton. The water was essentially fresh and mostly distant from surface drainage channels. The general fauna included ostracods and bathynellid syncarids, harpacticoid copepods, oligochaetes, microturbellia and nematodes. Outflows from the water mounds to the west of the sample area support a rootmat community that is rich in fauna in shallow cave environments (Jasinska, *et al.* 1996). All the copepods mentioned herein came from a restricted area of the Gnangara Mound (South) in an area of upward leakage from the Mirrabooka sandstone aquifer, which is of Cretaceous age, with salinity less than 500 mg L^{-1} TDS and the only associated fauna comprised ostracods and oligochaetes.

Yule and De Grey Rivers – respectively in the Pilbara Province (Whincup 1967) and the Canning Basin (Davidson 1975). There samples were taken from unused bores in the current freshwater production borefield (Water Corporation) located in these sand aquifers. Samples were taken at 18 locations (13 in the Yule) and the associated fauna included ostracods, amphipods (Melitidae) and bathynellid syncarids.

Port Hedland and Cossack – A single sample was taken at each site from early historical wells. Associated fauna includes ostracods.

MATERIAL AND METHODS

In October 1996 a brief reconnaissance survey of some groundwaters was conducted in northwestern Australia. Groundwater was sampled with haul nets (350 μm mesh size) predominantly from groundwater monitoring bores — some samples were taken from pastoral wells and from river gravels by the Karaman-Chappuis method — in aquifers along the Western Fortescue Plain (Millstream) and the lower Fortescue (Mardie Station) and Robe Rivers (Yarraloola Station: Map 1). Minor sampling was undertaken at Cossack, Port Hedland, and aquifers in the De Grey and Yule Rivers. Some samples from the Perth Basin were also examined (Map 1).

All samples were sorted while alive under a dissecting microscope, preserved in 70% alcohol and assigned a field number (BES number).

Permanent mounts were made in commercial polyvinyl-lactophenol medium. Dissected specimens were drawn at magnifications of 400x and 1000x, the latter using an oil immersion lens and "camera lucida" mounted on a Leitz Laborlux D phase-contrast microscope. Type material is deposited in the Western Australian Museum (WAM).

Terminology applied to body and appendages is according to Huys and Boxshall (1991).

SYSTEMATICS

Family Cyclopidae Burmeister, 1834 emend. Dana, 1846

Subfamily Halicyclopinae Kiefer, 1927

Genus *Halicyclops* Norman, 1903

Halicyclops rochai sp. nov.
Figures 1–21

Material Examined

Holotype

♀ (WAM C 24171), bore 4A, Yarraloola Station, Robe R., Western Australia, Australia (BES 4061), 21°34'S, 115°51'E, 24 October 1996, W.F. Humphreys.

Paratypes

Australia: Western Australia: 1 ♂, 1 juv. (WAM C 24172), Two Mile Well, Mardie Station, Fortescue R. (BES 4030), 21°10'S, 116°00'E, 23 October 1996, W.F. Humphreys; 1 ♂ (WAM C 24173), bore 15A, Yarraloola Station, Robe R. (BES 4071), 21°30'S, 115°46'E, 24 October 1996, W.F. Humphreys; 2 ♂ (WAM C 24174), bore 8A, Mardie Station, Fortescue R. (BES 4093), 21°10'S, 116°05'E, 25 October 1996, W.F. Humphreys; 2 ♀ (WAM C 24175), bore 1A, Yarraloola Station, Robe R. (BES 4059), 21°35'S, 115°53'E, 24 October 1996, W.F. Humphreys.

Description

Female

Length of holotype, excluding caudal setae, 538 µm; paratype 530 and 563 µm. Rostrum (Figure 10) subtriangular in frontal view, with 6 sensilla. First pedigerous somite fused with the cephalosome forming cephalothorax.

Genital double-somite (Figure 11) wider than long. Seminal receptacle as in Figure 11. Hyaline fringes of urosomites crenulate dorsally and ventrally.

Anal somite (Figure 14) bearing row of spinules along posterior margin and a pair of sensilla. Anal operculum not well defined.

Caudal rami (Figures 11, 14) about as long as wide, with 6 setae. Posterolateral seta slightly shorter than terminal accessory seta; dorsal seta very long, more than twice longer than terminal accessory seta; setation of the outer and inner terminal setae as in Figure 15.

Antennule (Figure 2) 6-segmented. Number of setation elements as follows: 8, 12, 5 + 1 spine, 6 + aesthetasc, 2, 10 + aesthetasc. Most setae sparsely plumose. Proximal segment with a row of small spinules at base of ventral surface.

Antenna (Figure 6): 3-segmented, excluding reduced coxa; basis with 2 inner plumose setae and one outer seta (exopod) overreaching the tip of the first endopodal segment; endopod segment 1 with 1 seta, segment 2 with 5 inner setae, 7 apical setae, and 2 rows of cilia on outer margin.

Labrum (Figure 9) with laterally serrate distal margin and row of 14 rounded teeth midway along margin, the outer ones stouter; paired transverse rows of spinules on anterior surface, rows of smaller spinules on posterior surface.

Paragnaths (Figure 8) are simple lobes bearing patches of fine setules and spinules, and 3 well developed pectinate setae.

Mandible (Figure 1) with coxal gnathobase armed with 8 sharp teeth, 1 pectinated element and 2 dorsal plumose setae; transverse row of 3 long spinules implanted subdistally on cutting blade. Palp represented by 2 unequal setae implanted directly on coxa.

Maxillule (Figure 3) consisting of praecoxa and 2-segmented palp. Praecoxal arthrite armed with 4 spines, and 7 elements on inner surface. Palp comprising coxobasis with 1 spinulate spine and 2 setae distally and 1 seta (representing exopod) on outer margin, and 1-segmented endopod bearing 3 long setae.

Maxilla (Figure 4) 4-segmented; praecoxa with single distal endite armed with 2 elements; proximal coxal endite represented by a single seta; distal coxal endite armed with 1 spine fused to endite and ornamented with 4 strong spinules, and 1 spine. Basis with endite bearing 2 stout elements and 1 seta. Endopod 1-segmented, bearing 3 stout elements plus 2 setae.

Maxilliped (Figure 5) 2-segmented; proximal segment bearing 3 setae, terminal segment two inner modified setae, 1 distal, stout modified seta and 2 subdistal setae.

Legs 1-4 armed as follows (Roman numerals representing spines; Arabic numerals setae):

	coxa	basis	exopod	endopod
leg1	0–1	1–I	I–1; I–1; III,1,4	0–1; 0–1; I,I+1,3
leg2	0–1	1–0	I–1; I–1; III,I+1,4	0–1; 0–2; I,II,3
leg3	0–1	1–0	I–1; I–1; III,I+1,4	0–1; 0–2; I,II,3
leg4	0–1	1–0	I–1; I–1; II,I+1,4	0–1; 0–2; I,II,II

Spine at inner corner of leg 1 basis (Figure 17) reaching about mid-length of endopod 2.

Endopod 3 of legs 2 and 3 (Figure 19) with proximalmost seta stiff, plumose basally and serrate distally.

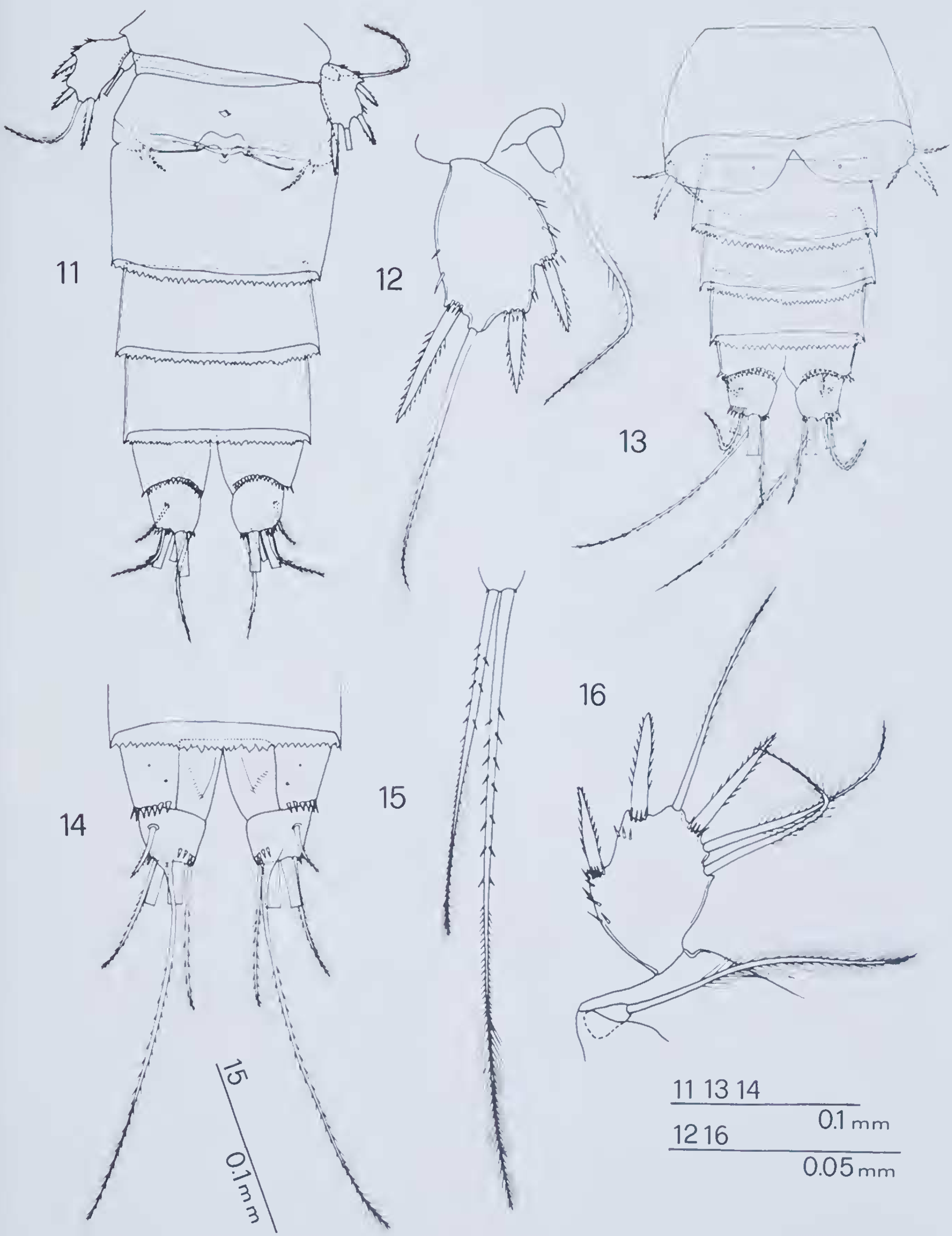
Leg 4 endopod 3 (Figure 18) about 2 times longer than wide, inner apical spine shorter than segment; both inner setae spiniform, serrate distally and plumose basally.

Leg 5 exopod (Figure 12) slightly longer than wide, armed with 3 spines and 1 seta, all spines shorter than segment.

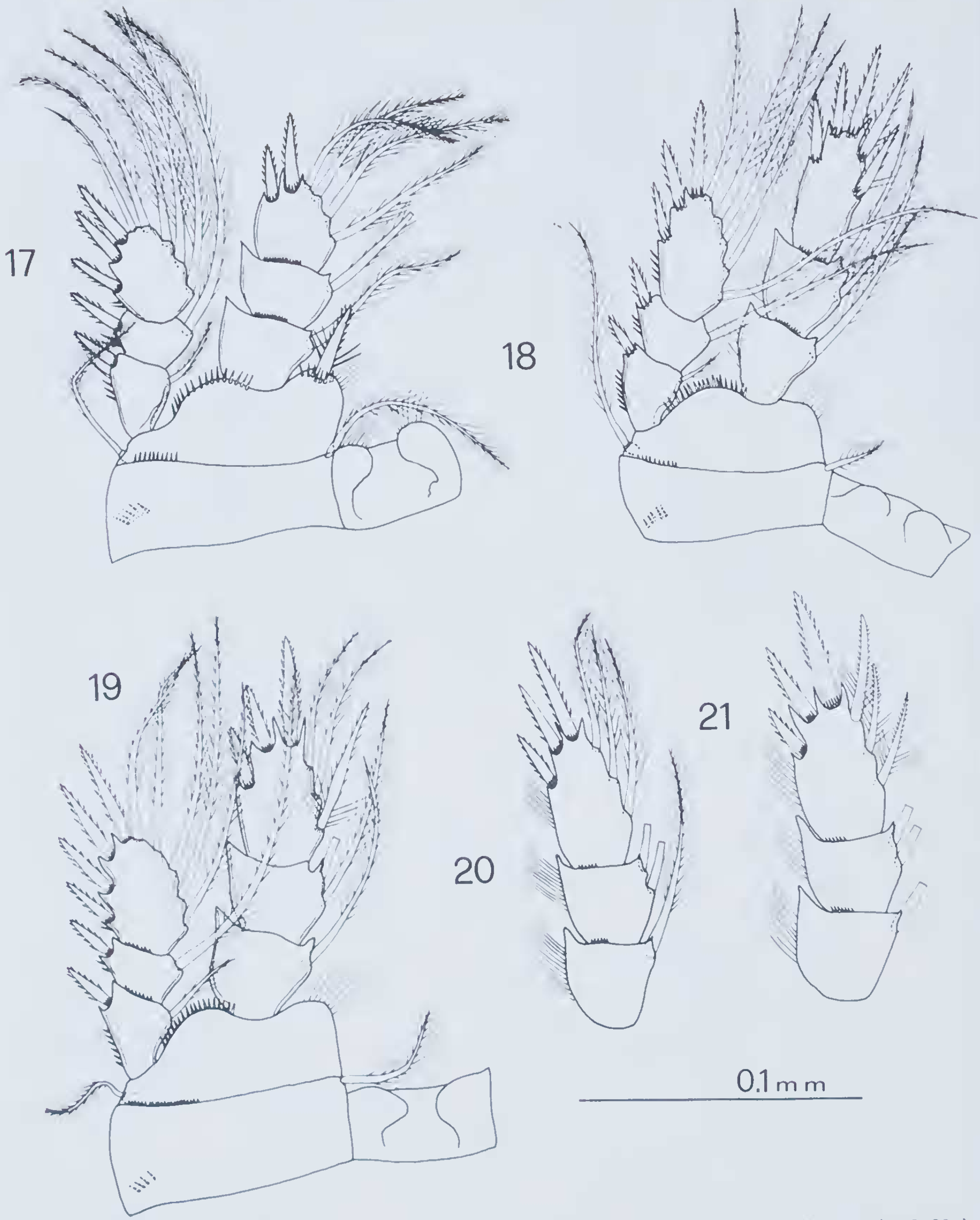
Male

Body length ranging from 458 to 556 µm (n=4). Caudal rami (Figure 13) about as long as wide.

Figures 1–10 *Halicyclops rochai* sp. nov., 2, 6, 8, 9 (holotype), 1, 3–5, 7, 10 (paratype): 1, mandible; 2, ♀ antennule; 3, maxillula, 4, maxilla; 5, maxilliped; 6, antenna; 7, ♂ antennule; 8, paragnaths; 9, labrum; 10, rostrum.



Figures 11–16 *Halicyclops rochai* sp. nov., 11, 14, 15 (holotype), 12, 13, 16 (paratype): 11, ♀ abdomen (ventral view), 12, ♀ leg 5; 13, ♂ abdomen (ventral view); 14, furcal rami (dorsal view); 15, furcal terminal setae, 16, ♂ leg 5.



Figures 17–21 *Halicyclops rochai* sp. nov., 17, 18 (holotype), 19–21 (paratype): 17, leg 1; 18, leg 4; 19, leg 2; 20, leg 2 endopod, 21, leg 3 endopod.

Antennule (Figure 7) 14-segmented. Setation as follows: 8 + 3 aesthetacs, 4, 5 + aesthetasc, 3, 1, 2, 1 + spine + aesthetasc, 2, 2 + aesthetasc, 2 spines, 1 + spine + aesthetasc, 1 spine, 1 + aesthetasc, 9 + 2 aesthetascs.

Leg 5 exopod (Figure 16) slightly longer than wide, with 2 outer spines, 1 apical seta, 1 inner serrate spine — slightly longer than outer spines — and 2 inner setae.

Leg 6 (Figure 13) represented by 2 setae and spine.

The male is identical to the female in all other respects. Only in one specimen (BES 4071) (Figures 20, 21), endopod 3 of legs 2 and 3 bears 3 inner normal setae and 3 spiniform setae, respectively.

Affinities

Halicyclops rochai fits within a Tethyan group of species ("*caridophilus*-group") characterized by the presence of 2 inner setae on the leg 5 exopod in the males.

At present, besides the new species, the group includes *H. caridophilus* Humes, 1974, from Borneo, *H. tetracanthus* Rocha, 1995, from Belize, and *Halicyclops* sp. nov., a new species from a cenote the Yucatan Peninsula, Mexico (Rocha *et al*., in press).

Halicyclops rochai differs from *H. caridophilus* by numerous characteristics, such as the mandibular palp bearing 2 setae (versus 1 seta), the different armature of the labrum, maxilliped and furcal rami, the different length of the genital double-somite, the morphology of inner seta on the endopod 3 of legs 2–3, the length of the spine on both the endopod and exopod 3 of leg 4. From *H. tetracanthus* it mostly differs by the number of spines on terminal endopodal segment of legs 2–3 (3 in *H. rochai*, 4 in *H. tetracanthus*) and by the armature of intercoxal sclerites of the legs 2 to 4 (naked in *H. rochai*, with rows of spinules on the free margin in *H. tetracanthus*), and by other characters, viz. the length of the genital double-somite (about as long as wide in *H. rochai*, longer than wide in *H. tetracanthus*), the armature of female leg 6, consisting of 1 short spine and 1 seta in *H. rochai*, 2 short spines and 1 seta in *H. tetracanthus*, and the ornamentation of the inner terminal furcal setae.

The new species is very close to *Halicyclops* sp. nov. Rocha *et al*. with which it shares, besides other characteristics, some peculiar features, such as the length of the dorsal and the terminal accessory furcal setae, the conspicuous length of the outer seta on the basis of legs 1 and 4, and the endopod of female legs 2–3 with proximalmost seta stiff, serrate distally and plumose basally.

From the above species, *H. rochai* is easily distinguished mostly by the length of the genital double-somite, the armature of male and female leg 6, and the length ratio between furcal posterolateral and terminal accessory setae.

Finally, the presence of 3 inner setae on the paragnaths is for the first time pointed out in *H. rochai*, since up to now this armature has been reported only in misophrioid copepods (Huys and Boxshall 1991).

However, we pointed out the same character also in *Diacyclops reidae*, *Diacyclops einslei* and *Diacyclops humphreysi* Pesce and De Laurentiis, 1996, herein described or discussed, as well as in other species we recently examined from Australia, such as *Paracyclops fimbriatus*, *Microcyclops varicans*, *Metacyclops mortoni* and *Mesocyclops brooksi*. The above observations led us to hypothesize that this feature may be more common in cyclopoid copepods than previously thought, and that it is significant in the systematics and phylogeny of cyclopid copepods. This feature should be more carefully observed and illustrated in future species descriptions.

Etymology

Specific epithet after C.E.F. Rocha in recognition of his valuable contribution to the knowledge of the halicyclopine copepods.

Subfamily Eucyclopinae Kiefer, 1927

Genus *Paracyclops* Claus, 1893

Paracyclops fimbriatus (Fischer, 1853)

Material Examined

Australia: Western Australia: 1 ♀ (WAM C 24176), groundwater monitoring bore (GWMW) AM 33A, Perth Basin (BES 4541), 31°50'S, 115°47'E, 6 March 1997, W.F. Humphreys and J. Waldock; 1 ♂ (WAM C 24177), same data as above, (BES 4544), same data as above; 4 ♀ (WAM C 24178), GWMW GM3, Perth Basin (BES 4546), 31°51'S, 115°49'E, same data as above; 1 ♀ (WAM C 24179), GWMW GM27, Perth Basin, (BES 4547), 31°54'S, 115°49'E, same data as above; 1 ♂ (WAM C 24180), GWMW GM28, Perth Basin, (BES 4549), 31°54'S, 115°50'E, same data as above; 1 ♀ (WAM C 24181), GWMW GM15, Perth Basin, (BES 4551), 31°52'S, 115°49'E, same data as above; 1 ♀ (WAM C 24182), GWMW GM34, Perth Basin, (BES 4558), 31°52'S, 115°50'E, same data as above.

Remarks

Paracyclops fimbriatus is widely distributed throughout the Australian continent, inhabiting both surface and ground fresh waters. According to some authors (Dussart 1969; Monchenko 1974; Plesa 1981) this species is characterized by a great variability that could include, as synonyms, the following taxa: *P. fimbriatus f. imminuta* Kiefer, 1929; *P. finitimus* Chappuis, 1929; *P. fimbriatus f. bromeliarum* Herbst, 1959 and *P. fimbriatus chiltoni* (Thomson, 1882).

Subfamily Cyclopinae Kiefer, 1927

Genus *Diacyclops* Kiefer, 1927

emend. Morton 1985, Reid et al. 1989

Diacyclops humphreysi Pesce and De Laurentiis, 1996

Material Examined

Australia: Western Australia: 3 ♀ (WAM C

24183), bore P8, Millstream aquifer (BES 3990), 21°35'S, 116°58'E, 19 October 1996, W.F. Humphreys; 4 ♀ (WAM C 24184), bore 7C, Millstream aquifer (BES 3967), 21°38'S, 117°01'E, 16 October 1996, W.F. Humphreys; 7 ♀, 1 ♂ (WAM C 24185), bore 1/96, Yule R., Water Corporation Borefield (BES 4466), 20°36'S, 118°18'E, 25 October 1996, W.F. Humphreys; 1 juv. (WAM C 24186), bore 3A, Yarraloola Station, Robe R. (BES 4083), 21°33'S, 115°52'E, 24 October 1996, W.F. Humphreys; 1 juv. (WAM C 24187), bore 8A, Mardie Station, Fortescue R. (BES 4093), 21°10'S, 116°05'E, 25 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24188), bore 37A, Mardie Station, Fortescue R. (BES 4043), 21°11'S, 116°03'E, 23 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24189), bore 15A, Yarraloola Station, Robe R. (BES 4071), 21°30'S, 115°46'E, 24 October 1996, W.F. Humphreys; 2 ♀ (WAM C 24190), Two Mile Well, Mardie Station, Fortescue R. (BES 4018), 21°10'S, 116°00'E, 22 October 1996, W.F.Humphreys; 2 ♀, 1 juv. (WAM C 24191), bore 3A, Mardie Station, Fortescue R. (BES 4038), 21°13'S, 116°02'E, 23 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24192), bore P2-77, Millstream aquifer (BES 4012), 21°35'S, 117°03'E, 20 October 1996, W.F. Humphreys; 15 ♀, 1 juv. (WAM C 24193), bore 7C, Millstream aquifer (BES 3969), 21°38'S, 117°01'E, 16 October 1996, W.F. Humphreys; 5 ♀ (WAM C 24194), same data as previous (BES 3968), same data as previous; 9 ♀ (WAM C 24195), bore 15B, Millstream aquifer (BES 3984), 21°45'S, 117°15'E, 18 October 1996, W.F. Humphreys.

Remarks

The new material which we examined of this species, as well as the re-examination of the holotype, revealed some new or previously overlooked characteristics regarding the labrum, paragnaths, basipodite of the antenna, male leg 6, length of furcal rami and armature of the endopod legs 2 and 3.

Labrum, paragnaths and armature of the basipodite of the antenna identical to those of *D. einslei*.

Spine and seta formula of legs 2–3 as follows:

	coxa	basis	endopod	exopod
leg2	0–1	1–0	0–1; 0–1; 1, I+1,2	I–0; I–1; III,1,3
leg3	0–1	1–0	0–1; 0–1; 1, I+1,2	I–0; I–1; III,1,3

Caudal rami 2.2 – 2.9 longer than wide, in ventral view, and with some cilia on dorsal inner surface.

Male leg 6 consisting of 2 setae and 1 spine.

Diacyclops reidae sp. nov.

Figures 22–40

Material Examined

Holotype

♀ (WAM C 24196), bore P1, Millstream aquifer, Western Australia, Australia (BES 4005), 21°34'S, 116°58'E, 19 October 1996, W.F. Humphreys.

Paratypes

Australia: Western Australia: 1 ♀ and 1 ♂ (WAM C 24197), same data as holotype; 1 juv. (WAM C 24198), bore 7A, Millstream aquifer (BES 4002), 21°35'S, 117°01'E, 19 October 1996, W.F. Humphreys; 2 ♀, 1 ♂ (WAM C 24199), bore 7C, Millstream aquifer (BES 3968), 21°38'S, 117°01'E, 16 October 1996, W.F. Humphreys.

Description

Female

Length of holotype, excluding antennule and caudal setae, 486 µm; range of length of paratypes 428–465 µm.

Genital double somite (Figure 35) wider than long, ornamented with 2 sensilla on dorsal surface and bearing copulatory pore mid-ventrally. Hyaline frills of urosomites weekly crenulate both dorsally and ventrally. Anal somite (Figure 35) bearing pair of dorsal sensilla and operculum with smooth posterior margin.

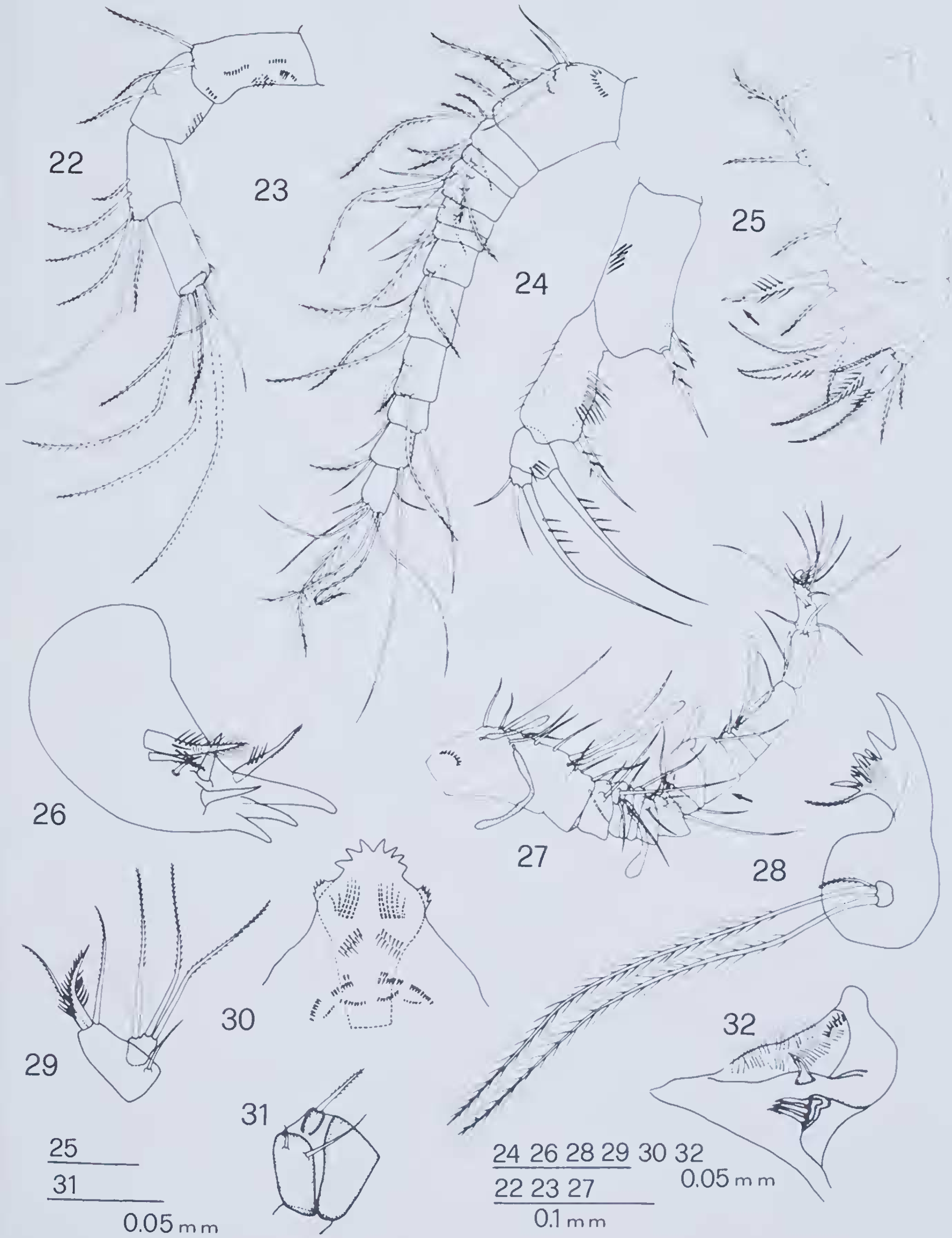
Caudal rami (Figure 35) 1.70–1.96 longer than wide, in ventral view. Only 6 setae present; seta I absent; seta II located on dorsal surface, about 75% of distance along ramus; seta VI about 2.5 times longer than seta III; seta IV and V well developed; seta VII about 2.4 times longer than ramus. Group of cilia present on dorsal inner surface, about 30% of distance along ramus.

Antennule (Figure 23) 12-segmented. Number of setation elements as follows: 8, 4, 2, 5, 2, 1+1 spine, 2, 3, 2+aesthetasc, 2, 3, 8. Most setae sparsely plumose. Proximal segment with row of small spinules at base of ventral surface.

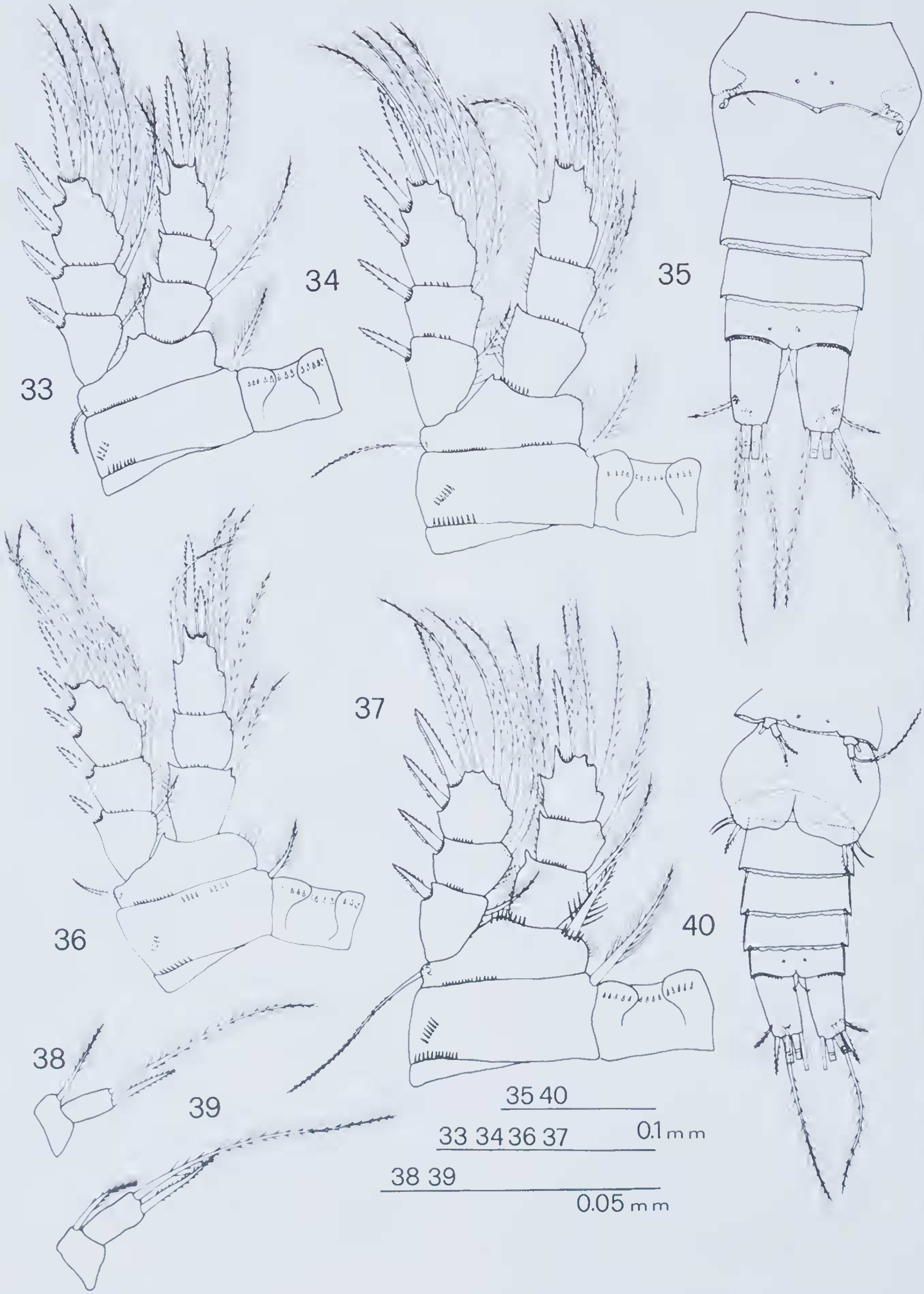
Antenna (Figure 22) 4-segmented, excluding unarmed coxa; basis bearing 2 spinulose setae around inner distal angle and ornamented with one spinule row along ventral margin, and 4 spinule rows on the dorsal side; exopodal seta absent. Endopod 3-segmented; first segment with inner medial seta and patch of spinules along the outer margin; second segment with 6 setae (2 along the inner margin, 4 along inner part of distal margin); third segment armed with 7 setae.

Labrum (Figure 30), posterior part convex and bearing 6–7 stout teeth, lateral corners strongly denticulate; remaining ornamentation as in Figure 30. Paragnaths (Figure 32) consisting of paired lobes, ornamented with usual rows of fine setules and 3 setulose spines, one stout spiniform process and a row of small spines along the inner margin.

Mandible (Figure 28) with well developed coxa with gnathobase; gnathobasic blades mostly simple, innermost dorsal surface with row of spinules, palp reduced, bearing 3 setae, one very short.



Figures 22–32 *Diacyclops reidae* sp. nov., 22–25, 30 (holotype), 26–29, 31, 32 (paratype): 22, antenna; 23, ♀ antennule; 24, maxilliped; 25, maxilla; 26, 29, maxillula; 27, 31, ♂ antennule; 28, mandible; 30, labrum, 32, paragnaths.



Figures 33–40 *Diacyclops reidae* sp. nov., 34–36, 37, 39 (holotype), 33, 38, 40 (paratype): 33, leg 2; 34, leg 3; 35, ♀ abdomen (ventral view); 36, leg 4; 37, leg 1; 38, ♂ leg 5; 39, ♀ leg 5; 40, ♂ abdomen (ventral view).

Maxillule (Figure 26), praecoxa bearing reduced 2-segmented palp (Figure 29). Praecoxal endite armed with 6 spinulose setae and 3 spines fused to segment. Proximal segment palp bearing 3 inner margin setae (one stout and spinulose) and an outer seta representing exopod. Distal segment of palp, representing endopod, armed with 3 plumose setae.

Maxilla (Figure 25) comprising partially fused praecoxa and coxa, basis and 2-segmented endopod. Praecoxa bearing one endite armed with 2 plumose setae, coxa with 2 endites, the proximal one bearing one plumose seta, the distal one bearing one seta and one bifid setulose spine; basis with a well-developed claw and 2 setae. First endopodal segment bearing 2 spinulose setae, second with 3 setae.

Maxilliped (Figure 24) 4-segmented, comprising syncoxa, basis and 2-segmented endopod. Syncoxa bearing 2 inner margin spinulose setae representing 2 vestigial endites, and rows of spinules along the outer margin. Basis armed with 2 inner spinulose setae and rows of spinules along the inner and outer margins. First endopodal segment bearing a single spinulose seta and spinules around its base. Second endopodal segment with a long spinulose seta and two shorter, naked setae.

Swimming legs 1 to 4, 3-segmented (Figures 34, 35, 36, 37). Intercoxal sclerites with rows of small spinules. Praecoxa represented by triangular sclerite, armed with row of small spinules. Coxa armed with inner plumose seta and ornamented with rows of small anterior and posterior spinules. Basis of leg 1 (Figure 37) with long outer seta, inner spine well overreaching the second endopodal segment, and ornamented with spinule row between rami. Outer spines on the exopods of legs 1–2 ornamented as in figs 37 and 33. Endopod 3 of leg 4 (Figure 36) about 1.7 times longer than wide, outer spine longer than segment and about twice longer than the innermost.

Spine and seta formula as follows:

	coxa	basis	endopod	exopod
leg1	0–1	1–I	0–1; 0–1; 1, I+1,2	I–1; I–1; II,1,3
leg2	0–1	1–0	0–1; 0–1; 1, I+1,2	I–1; I–1; III,1,3
leg3	0–1	1–0	0–1; 0–2; 1, I+1,2	I–1; I–1; III,1,3
leg4	0–1	1–0	0–1; 0–2; 1, II,2	I–1; I–1; III,1,3

Fifth leg (Figure 39) 2-segmented; protopodal segment narrow, bearing outer plumose seta; exopodal segment about twice as long as wide, bearing 1 plumose seta and one setiform spine distally, both longer than segment.

Sixth leg (Figure 35) bearing 2 spines and one seta.

Male

Body (Figure 40) length from 319 to 375 µm. Antennule (Figures 27. 31) digeniculate, 16-segmented. Setation as follows: 8+3 aesthetascs, 4, 2, 2+aesthetasc, 2, 2, 2, 2, 1+spine+aesthetasc, 2, 1+spine, 2 spines, spine+aesthetasc+striated element, 1, 2 striated element, 11.

All other appendages as in female except for sixth leg (Figure 40), forming opercular plates bearing one plumose spine and 2 setae.

Affinities

Diacyclops reidae is discussed together with *Diacyclops einslei.*

Etymology

The species is dedicated to J.W. Reid, distinguished copepodologist, in recognition of her valuable contributions to knowledge of the cyclopine copepods.

Diacyclops einslei sp. nov.
Figures 41–50

Material Examined

Holotype

♀ (WAM C 24200), bore P2-77, Millstream aquifer, Western Australia, Australia (BES 4012), 21°35'S, 117°03'E, 20 October 1996, W.F. Humphreys.

Paratypes

Australia: Western Australia: 3 ♀, 1 ♂ (WAM C 24201), same data as holotype.

Description

Female

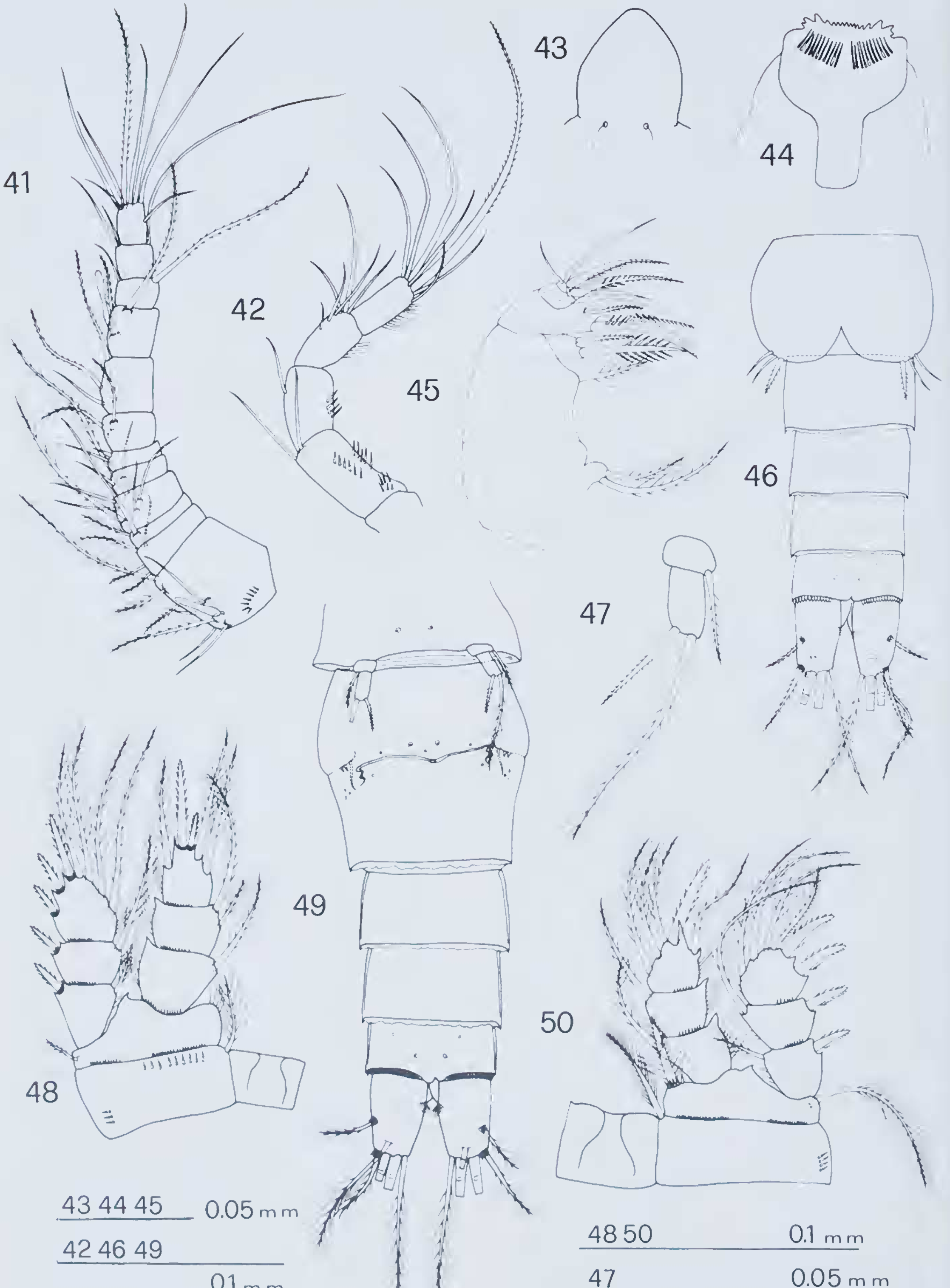
Length of holotype, excluding antennule and caudal setae, 404 µm; range of length of paratypes 381–419 µm. Rostrum (Figure 43) subtriangular, with 2 sensilla.

Genital double somite (Figure 49) slightly longer than wide, ornamented with 2 sensilla on dorsal surface, 2 pores on ventral surface and 2 group of pores dorsally. Anal somite bearing pair of dorsal sensilla and 2 pores.

Caudal rami (Figure 49) about 1.5 longer than wide, in ventral view. Only 6 setae present; seta I absent; seta II located on dorsal surface, about 75% of distance along ramus; seta VI about 2 times longer than seta III; seta IV and V well developed; seta VII less than twice longer than ramus. A group of cilia is present on dorsal inner surface, about 30% of distance along ramus.

Antennule (Figure 41) 12-segmented: Number of setation elements as follows: 8 + aesthetasc, 4, 2, 5, 2, 1+1 spine, 2, 3, 2+aesthetasc, 2, 3, 8. Most setae sparsely plumose. Proximal segment with a row of small spinules at the basis of ventral surface.

Antenna (Figure 42) 4-segmented, excluding unarmed coxa. Basis bearing 2 setae around inner distal angle and ornamented with one spinule row along ventral margin, and 3 spinule rows on the dorsal side; exopodal seta absent. Endopod 3-



Figures 41–50 *Diacyclops emslei* sp. nov., 45, 47–50 (holotype), 41–44, 46 (paratype): 41, ♀ antennule; 42, antenna; 43, rostrum; 44, labrum; 45, maxilla; 46, ♂ abdomen (ventral view); 47, ♀ leg 5; 48, leg 4; 49, ♀ abdomen (ventral view); 50, leg 1.

segmented; first segment with inner medial seta and patch of spinules along the outer margin; second segment with 6 setae (2 along the inner margin, 4 arranged along inner part of distal margin); third segment armed with 7 setae.

Labrum, posterior part bearing numerous teeth, the lateral ones stronger, remaining ornamentation as in Figure 44. Paragnaths, mandible, maxillule and maxilliped without differences as compared to *D. reidae*; maxilla similar to that of *D. reidae* except for the spine on the distal coxal endite not bifid.

Swimming legs 1 to 4, 3-segmented. Coxa armed with inner plumose seta and ornamented with rows of small anterior and posterior spinules. Basis of leg 1 with long outer seta, inner spine reaching about one half of the second endopodal segment. Outer spines on the exopods of legs 1 ornamented as in Figure 50. Endopod 3 of leg 4 (Figure 48) about 1.2 times longer than wide, outer spine much longer than segment and more than twice longer than the innermost.

Spine and seta formula as follows:

	coxa	basis	endopod	exopod
leg1	0–1	1–I	0–1; 0–1; 1, I+1,2	I–1; I–1; II,1,3
leg2	0–1	1–0	0–1; 0–1; 1, I+1,2	I–1; I–1; III,1,3
leg3	0–1	1–0	0–1; 0–2; 1, I+1,2	I–1; I–1; III,1,3
leg4	0–1	1–0	0–1; 0–2; 1, II, 2	I–1; I–1; III,1,3

Fifth leg (Figure 47) 2-segmented; protopodal segment narrow, bearing outer plumose seta; exopodal segment about twice as long as wide, bearing 1 plumose seta and one setiform spine distally, both longer than segment.

Sixth leg (Figure 49) bearing 2 spines and one seta.

Male

Body length 362 μm (Figure 46). Antennule digeniculate, 16-segmented. Setation as in *D. reidae*.

All other appendages as in female except for sixth leg, forming opercular plates bearing 1 plumose spine and 2 setae.

Discussion and comparison

Diacyclops einslei and *Diacyclops reidae* belong to the *Diacyclops crassicaudis*-complex (Reid, 1992), characterized by a 12-segmented antennula and all rami of the swimming legs 3-segmented. Within this complex both the new species share with *D. humphreysi*, *D. alticola* Kiefer, 1935, from India and *D. longifurcus* Shen and Sung, 1963, from China, the peculiar characteristic of the inner apical spine of the leg 4 endopod shorter than the outer.

Diacyclops reidae and *D. einslei* are very close to *D. humphreysi*. The main differences seem to the shorter caudal rami, the presence of inner seta on the P1–P4 exopod 1 (versus seta absent), the presence of 2 setae on the P3 endopod 2 (versus 1 seta only).

Diacyclops reidae and *D. einslei* are easily distinguished by remarkable differences, such as the different armature of the basipodite of the antenna, the different morphology and spines of the labrum, the presence of a bifid spine on the distal coxal endite of the maxilla in *D. reidae* (versus spine not bifid), intercoxal sclerites of swimming legs with row of spinules in the *D. reidae* (versus naked intercoxa), the length of the P4 endopod 3 (about 1.2 and 1.7 times longer than wide in *einslei* and *reidae* respectively), and the length of the genital double-somite, wider than long in *reidae*, slightly longer than wide in *einslei*.

Etymology

The species is dedicated to U. Einsle in recognition of his fundamental contribution to knowledge of copepods.

Genus *Microcyclops* Claus, 1893

Microcyclops varicans (G.O. Sars, 1863)

Material Examined

Australia: Western Australia: 1 ♀ (WAM C 24202), Corner Well, Mardie Station., Fortescue R. (BES 4034), 21°10'S, 116°01'E, 23 October 1996, W.F. Humphreys; 1 ♀, 1 ♂ (WAM C 24203), shingle, Karaman-Chappuis method, De Grey River (BES 4471), 20°19'S, 119°15'E, 26 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24204), bore 13A, Yarraloola Station, Robe R. (BES 4078), 21°29'S, 115°48'E, 24 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24205), Two Mile Well, Mardie Station, Fortescue R. (BES 4084), 21°10'S, 116°00'E, 24 October 1996, W.F. Humphreys.

Remarks

Microcyclops varicans is a cosmopolitan and ubiquitous cyclopid, known from both epigean and underground fresh and brackish water bodies throughout the Australian continent (Pesce *et al.* 1996a).

Genus *Metacyclops* Kiefer, 1927, sensu Lindberg, 1961

Metacyclops mortoni Pesce, De Laurentiis and Humphreys, 1996

Material Examined

Australia: Western Australia: 1 ♀ (WAM C 24206), Old Well, Pt. Hedland (BES 4462), 20°20'S, 118°38'E, 26 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24207), Town Well, Cossack (BES 4465), 20°41'S, 117°11'E, 25 October 1996, W.F. Humphreys.

Remarks

Metacyclops mortoni is apparently a stygobiont species, endemic to northwestern Australia – it is known from groundwaters of the Cape Range peninsula, Ashburton River, Port Hedland and Cossack (Pesce *et al.* 1996a).

Genus *Mesocyclops* G.O. Sars, 1914

Mesocyclops brooksi Pesce, De Laurentiis and Humphreys, 1996

Material Examined

Australia: Western Australia: 1 ♀ (WAM C 24208), bore CP3 11/81, Millstream aquifer (BES 4010), 21°36'S, 117°04'E, 20 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24209), Irwin Well, Millstream aquifer (BES 4016), 21°40'S, 117°09'E, 20 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24210), Corner Well, Mardie Station, Fortescue R. (BES 4034), 21°10'S, 116°01'E, 23 October 1996, W.F. Humphreys; 1 ♀ (WAM C 24211), Two Mile Well, Mardie Station, Fortescue R. (BES 4084), 21°10'S, 116°00'E, 24 October 1996, W.F. Humphreys.

Remarks

Mesocyclops brooksi is apparently a stygobiont species, endemic to northwestern Australia – it is known from aquifers at Millstream and on the Fortescue and Ashburton Rivers (Pesce *et al.* 1996a).

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